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ON LEARNING MAPS

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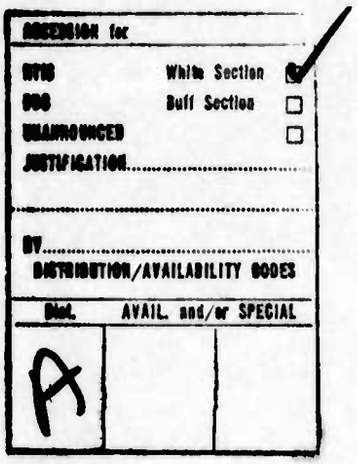
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This report describes a study of how maps are learned. Subjects studied a simple map under various conditions and then answered questions about the map and drew the map from memory. It was found that: (a) local relations are learned before large-scale relations; (b) different types of map information must be presented simultaneously for effective integration; (c) reading a story relevant to the map is more helpful in remembering the map than spending the same amount of time copying the map.

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On Learning Maps

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The exploratory studies reported here concentrate on two areas: (1) The process by which maps are learned: Is there a general strategy people develop when they study a map? (2) Processes of storage and retrieval of map information: Are there special organizations which are more effective than others in storing map memory?

A map is a hybrid of the linguistic and pictorial systems. It is symbolic in the sense that it bears little or no resemblance to the space which it describes. The red line which symbolizes a highway has little similarity to the visual appearance of the actual highway. In this sense a map can be construed to be like a language, with both a surface structure and a deep level meaning. The organization of the map symbols is a central issue in learning, comprehending and remembering a map. Three aspects of this organization seem to be particularly important: (a) the coordinate system; (b) the "shape world;" (c) the overall integral relationships.

The coordinate system is the most obvious element of map organization. A map can be analyzed in terms of top and bottom (north and south), and left and right (west and east). The map symbols are organized and fixed in two dimensions in a way which preserves values such as shapes, distances and directions.

Shapes may be described by means of a coordinate system. However, many shapes are familiar and carry names. Thus, even though a square can

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be easily described by the coordinate system, recognizing it as a square affects its psychological processing (Reed, 1973; Riley, 1964). One way of comprehending a map is to organize the lines into familiar figures. Perceiving and thinking in terms of a familiar figure can be valuable even if the figure is deviant from its stereotypic shape, as long as this deviation is definable. Thus, one can comprehend a specific figure as "this rectangle with the tail at the upper left corner," or "this shape which is similar to an inverted B." There is also the possibility that a particular shape will be a combination of a certain number of familiar shapes (cf. Leeuwenberg, 1971), and some correcting rules will be used to supplement the definition. Practically every unfamiliar shape can eventually be defined by combining familiar figures or their parts and by applying correcting rules.

The third element in map grammar is the overall integration of the map's subparts. Orientation and location are aided by the coordinate system. However, the real practical test of a reproduction of a map is not just how closely each element approaches its original location or original shape, but also how well everything fits together.

When subjects learn a geographic map, they are expected to remember names of objects like cities, rivers, mountains and highways. Memory for these names seems to require cognitive processing different from and perhaps independent of the processing mentioned above. Yet memory for names and titles is essential for practical reasons, since in order to demonstrate knowledge of the map, the labels of objects included in it must be used correctly. It seems possible that some subjects will have good memory for forms but poor memory for labels, and vice versa.

Analysis of Map Descriptions

In the first phase of this study of map learning, a group of 14 subjects was asked to learn a map (Figure 1), and then to describe it in writing. Of course, people can write about only that part of a map that can be put into words. Verbal analysis of map learning is obviously limited in its value, but may still be helpful. As expected, most people used coordinate lexical items typical for describing directions and locations, including expressions like "the northernmost city" or "the southern routes." Some people were quite specific in their use of the coordinate expressions, using phrases like "half the way north" or "directly east." Some mentioned the approximate angle between objects.

With one exception, all of the participants included at least one shape in their description of the map. Half of them mentioned the S shape of the river. Others mentioned terms like "a concave road," "a Y intersection," "a fork intersection," "the reverse-7 shape of the mountain range," "the river as an integral sign," "the highways' form of an oval" ("parallelogram," "diamond," or "arc"), and "river elbows."

The cities mentioned in the map were usually referred to through connections to the highways and major objects such as the river and mountains. Usually the highway was described first, followed by the cities along the highway. Sometimes the description of the highway was combined with reference to the cities involved. An example of the former is: "Interstate 11 is on the west side of the river. It has Romney on it on the north and Sunyside on the south." An example of the latter is: "Highway 5 starts with Danville which is a little bit northeast of Sunyside and goes north through Burkesville which is just a little

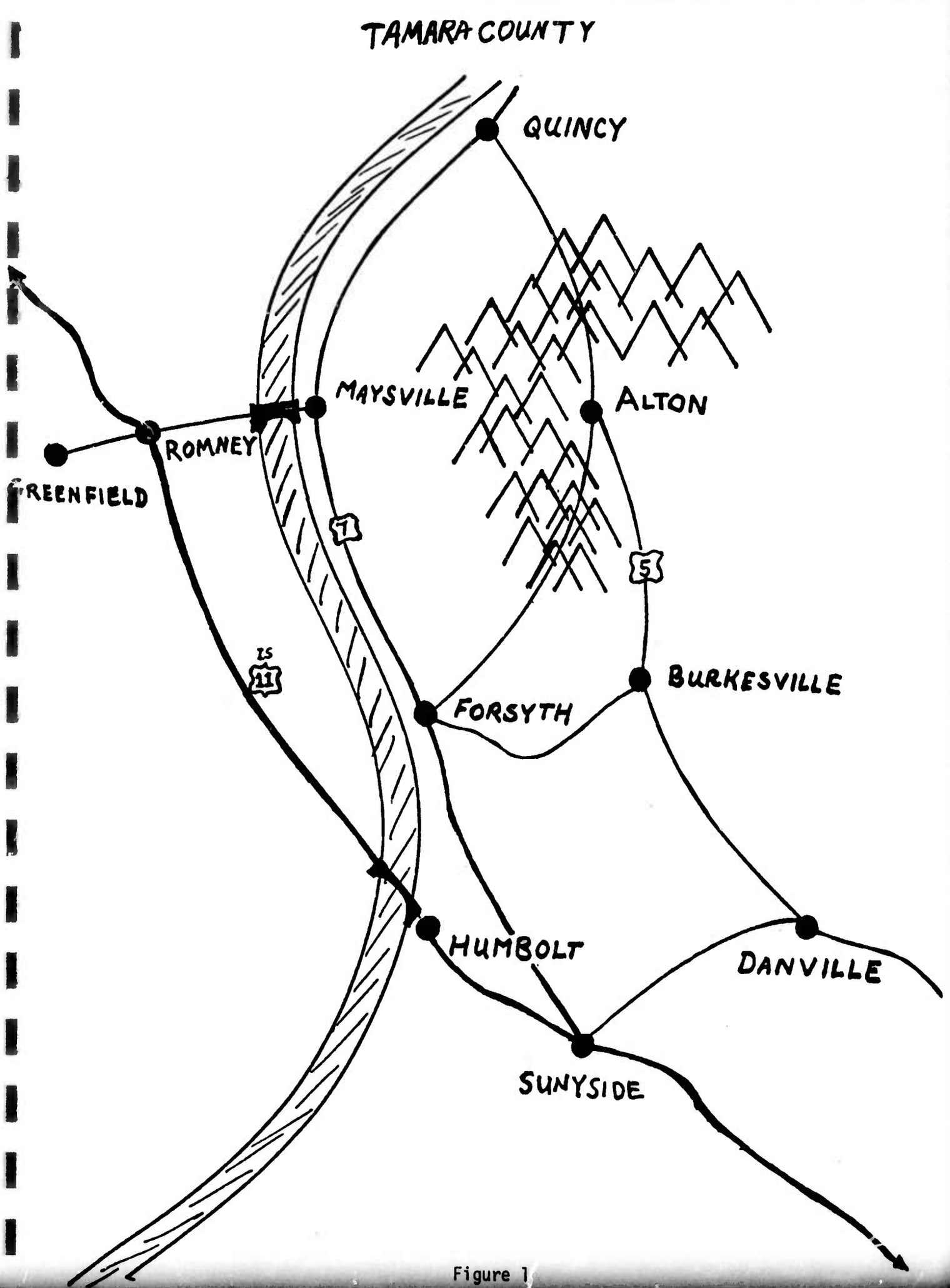
TAMARA COUNTY
QUINCY
MAYSVILLE
ALTON
ROMNEY
GREENFIELD
7
5
IS
11
BURKESVILLE
FORSYTH
HUMBOLT
DANVILLE
SUNYSIDE

Figure 1

northeast of Forsyth, up through Alton which is up in the mountains, just east of Maysville, and then through Quincy." One of the participant's descriptions included a comment that obviously resulted from the creative use of imagination: "There is a valley running from the river east and on a clear day you can see from Maysville all the way east to Alton, and from Forsyth all the way east to Burkesville." Apparently, this subject visualized being a part of the landscape and in an attempt to make the whole map more meaningful, added some propositions which helped to integrate the information given by the map. In summary, analysis of the map descriptions shows that the subjects made use of words that denoted coordinate relationships, identified familiar shapes, and associated city locations with the spatial concepts.

Experimental Work

Suppose a map is learned. How can we detect the organization of the map elements in a person's memory? One way is to name various parts of the map and then to use these names as pegs for the detection of map information. In the map used in these experiments there is a river, a mountain range, three major roads, and ten cities (Figure 1). In order to make the detection of map organization possible, cities were located at all road intersections and the roads were given names. There are also two bridges--the northern and the southern. Given the cities at major intersections, the road names, the mountains and the river, it is possible to cue several hypothetical systems of memory organization and realize their relative effectiveness.

Learning a map--as well as learning any other visual stimuli--takes time and requires the activation of several processes. How is it possible to detect the temporal order by which these processes are organized? In this study, by providing different amounts of time for the learning activity, it was hoped that information about the strategies of map learning could be gained. How can the quality of map recall be measured? The scoring system must be able to assess the assumptions about the possible ways of organizing map information.

Several elements of the map can be conceived as schemes to which other map elements may be connected. Cities, for example, can be conceived as connected to main highways, rivers, or mountains. The highway or the river thus becomes a framework for encoding the other locations and its label can be used as a cue for retrieving the whole frame. In the process of forming a framework, subjects should also incorporate into it the various relevant details, such as city location and bridges (cf. Asch, Hay & Diamond, 1960).

Map elements might also be encoded in terms of their coordinate position. Objects appearing on the map can be learned as being in the northern, southern, or central portion of the map.

Proximity between map elements may also play a role in the integration of map information. Things which are seen closely together are likely to be remembered in conjunction. This is an old rule of perception and memory which may have significance in the processes involved in learning maps.

Finally, there is a need to assess the overall integration of the map elements. When a map is fully memorized, people should be able to "read" the map from north to south, west to east, or along the highway system.

In other words, they must comprehend the interrelations between the various organizations of map information.

Measuring Map Learning

Recall of items as organized by the coordinate system was assessed by two kinds of questions. The first asked for the most northern, southern, eastern and western cities on the map. The second asked for coordinate relationships between cities: "Which city is directly south of Alton?"

To assess the effect of proximity among map elements on the recall of map information, two kinds of questions were formulated. The first dealt with proximity between nearby cities: "Which city is between Alton and Danville?" The second dealt with the proximity of a city to a geographical object: "Which city is in the mountains?"

In order to assess how various items are organized in conjunction with major figures of the map, the associative memory between cities and highways was tested. In one set of questions subjects were asked to name two cities along a particular highway in no specific order. In another set of questions subjects were asked to name all the cities located on a particular highway in a predetermined order.

Two types of questions were formulated to assess overall integration of the map information. In the first one, subjects were asked to mention all the cities from one end point of the map to another along the shortest route. In most cases the two end points were located at the two ends of a highway, but not always. The other question was aimed at assessing overall integration of the map. The subjects were told a list of ten city names.

The list actually followed a particular route on the map, but the route was not told to the subjects. They were simply asked to write the names down in the original order. The assumption is that to do the task perfectly (or with only a single miss), a subject must have a good internal organization of the list, probably recognizing the actual route that was followed.

How can the quality of a map drawing be evaluated? One obvious way is to compute point to point deviations of the reproduced map from the original one. However, aside from the fact that such computation may be difficult to perform, this method would not evaluate much of the subject's knowledge that might be inferred from the map reproduction. Among these are values such as similarity of shapes and proper placement of figures on the map.

In the scoring system developed here, an attempt was made to reduce subjectivity to a minimum. This was done by breaking the map into small fractions so that each scoring decision applies to only a subpart of the map. If consistent criteria are applied, such a decision can turn out to be sufficiently reliable. The fractioning of the map was done with regard to the major map figures. Each figure was divided into its graphical subelements. Map divisions were made where the figural contours change their directions or shape. Subjects received zero credit if the particular element did not exist on the map. They received half credit if the element was depicted with the wrong shape or direction (a deviation of more than 45°). Full credit was given if the particular element was judged to be quite similar to its equivalent in the original map.

Experiment 1

The first experiment was designed to obtain information about the temporal order of processes involved in map learning. If the map is well learned--when enough time is given to the subjects and the information of the map is well integrated, there should be no difference between the effectiveness of the various memory organizations, since each one of them has been sufficiently elaborated. If the time given for learning the map is limited, some processes will be more affected than others. This study examines the effect of limited time.

Method

Two groups of subjects were asked to learn the same map. The first group was given as much time as they indicated they needed (approximately 12 minutes). The second group was given only half the amount of time permitted the first group. Immediately after the learning period, subjects were given (orally) the test questions described above, and required to write their answers. Later they were also asked to draw the map.

There were 14 subjects in the "unlimited time" group and 13 subjects in the "limited time" group. Subjects were undergraduate students at the University of California, San Diego who were paid $2.00 an hour.

The map and the answer sheets were organized in a booklet, and the experimenter made sure that pages in the booklets were turned simultaneously by all subjects.

Results and Discussion

The results are shown in Table 1. With the exception of recall by spatial organization, all the scores were between 80 and 100% correct for

Table 1

Mean percentage of correct scores in each category of map memory with limited and unlimited learning time. In the "unlimited time" group N = 14. In the "limited time" group N = 13.

Categories of Map Memory and Examples	Unlimited Time	Limited Time	Statistics
1a. Edges of the coordinate system (i.e., What is the most northern city?)	81	79	N.S.
1b. Orientation between cities (i.e., Which city is directly south of A?)	91	67	$t = 2.27$ $p < .05$
2a. Associations to nearby cities (i.e., Which city is between A and C?)	93	83	N.S.
2b. Associations to nearby landmark (i.e., Which city is in the mountains?)	86	87	N.S.
3a. Associations between cities and routes (i.e., Name two cities on Rt. 5)	96	72	N.S.
3b. Recall of all the cities along a route (i.e., Name the cities on Rt. 7 going south)	79	62	$t = 2.14$ $p < .05$
4a. Cities between end points (i.e., Name the cities from A to D)	81	49	$t = 3.3$ $p < .01$
4b. Recall by spatial organization (i.e., Repeat these ten names. . .)	50	23	$z = 1.42$ $p < .1$
Map Quality	89	81	N.S.

the "unlimited time" group.

Limiting the amount of time available for learning has no effect on subjects' memory of local connections between nearby cities and between a city and a topographic landmark. It is tempting to suggest that in the process of learning maps, these associations are formed first and most powerfully.

Subjects with restricted time were not hampered in identifying the most remote cities on the map. It is assumed that memory that a particular city is located on the very top (north) of the map is functionally similar to memory of the relationship between a city and a particular geographic landmark.

The situation is different when subjects are required to identify coordinate relationships between various cities within the map. The "limited time" subjects did not do well in indicating the exact orientations between neighboring cities. It may be that although proximity between locations is easily remembered, the exact coordinate relationship between the items requires more processing.

Tests for overall integrative memory of the map show that people can succeed only after considerable processing. There were two kinds of questions in this category. In the first, subjects were required to recall the names of cities between two end points of the map (4a in Table 1). In the second, they were expected to realize the existence of spatial organization which makes the memory of ten names easier or possible (4b in Table 1). In these two tests restriction of learning time had a drastic effect on subjects' performance. With regard to the first task, it could

be expected that if time restriction affects the memory of connections between several cities and a highway (as mentioned above), it would certainly affect the recall of the same, or a similar, list of names when subjects are not told that the items are all connected by a particular frame (i.e., a highway).

The second task was the most demanding one. Only subjects who had learned the map well could actually answer it. Of the "unlimited time" group, 50% answered this question correctly, but only 23% of the "limited time" group did so.

Experiment 2

One possible strategy for learning a map is to identify schemes like rivers, highways or mountains, and then to associate nearby locations with the schemes and store them together. At some stage (and perhaps simultaneously), the learner of the map must pay attention to the relations between map elements--how the schemes interrelate. This experiment studies the effect of presenting each of the map's schemes separately, so that processing the symbols and identifying the schemes is made easier. In this way, a subject learns the layout of one scheme before relating it to the others. The interrelations among several schemes as they appear together on the map may only be learned later on.

Presenting the map in piecemeal fashion has a serious control problem. A claim can be made that any kind of stepwise presentation of a map, no matter how the steps are derived, decreases the amount of information to be learned in each single presentation and is bound to facilitate learning. To control for this, the control group can be given the map in a different piecemeal fashion. The map was divided into three sections and the control group was given one third of the whole map at a time.

Method

There were two groups, the "schemes" group and the "sections" group. Each group received one third of the total map information in three consecutive cumulative presentations. The "schemes" group received one kind of information in the first presentation (e.g., the mountains and the river); an additional type was added in the second presentation (e.g., the highways); and then in the third presentation the rest of the map information was added (e.g., the city locations). Thus, the entire map

was presented at the third presentation. The "sections" group received one section of the map in the first presentation (e.g., the northern part), an additional section in the second presentation, and all sections of the map in their third presentation. The order of presentations of either sections or schemes was rotated within each group to balance presentation time for each particular item on the map. Each successive portion of the map was presented after a 3-minute interval.

Subjects for this experiment were undergraduate students whose participation in the experiment was part of the requirements in an introductory course in Psychology. Twelve subjects took part in each one of the two groups.

Stimuli were included in a booklet prepared especially for each subject. Both groups were tested together in a classroom.

Results and Discussion

The results are shown in Table 2. Two of the comparisons between the groups turned out to be significantly different in favor of the group who learned the map in sections. The significant results were obtained with the more difficult tests--i.e., the recall of all the cities along a particular highway and the recall of all cities by recognizing an implicit organization. Note that even though only two of the tests resulted in significant differences, the differences in all nine tests were in the same direction. Considering the small sample size, this pattern of results may suggest a reliable difference between the two groups.

Table 2

Mean percentage of correct scores in each category of map memory for learning by schemes and learning by sections. There were 12 subjects in each group.

Categories of Map Memory and Examples	Schemes	Sections	Statistics
1a. Edges of the coordinate system (i.e., What is the most northern city?)	75	83	N.S.
1b. Orientation between cities (i.e., Which city is directly south of A?)	75	81	N.S.
2a. Associations to nearby cities (i.e., Which city is between A and C?)	81	83	N.S.
2b. Associations to nearby landmark (i.e., Which city is in the mountains?)	77	83	N.S.
3a. Associations between cities and routes (i.e., Name two cities on Rt. 5)	76	89	N.S.
3b. Recall of all the cities along a route (i.e., Name the cities on Rt. 7 going south)	55	80	$t = 2.58$ $p < .01$
4a. Cities between end points (i.e., Name the cities from A to D)	63	74	N.S.
4b. Recall by spatial organization (i.e., Repeat these ten names. . .)	8	42	$z = 3.7$ $p < .001$
Map Quality	83	86	N.S.

Why is it that those persons who learned the map section by section instead of scheme after scheme had, on the average, the same or sometimes an even better memory of the map? The answer must take into account advantages and disadvantages of both strategies. Learning the schemes in separation seems to have an obvious advantage in comprehending the symbolic structure of the map. The identification of schemes such as the highway system or the mountains is easier in this way. Learning the map by sections, one always has to cope with the multischematic configuration of the map simultaneously. Moreover, learning by section is also difficult because the subject can learn only a fraction of the scheme until the whole map is combined together, and may have trouble relating one piece of the scheme to the others.

Apparently another consideration should also be taken into account: A major factor in learning maps is that all of a map's schemes are interrelated as if they are superimposed one on top of the other. When subjects learn one scheme at a time, they might have difficulty seeing how all the schemes fit together. Without integration, whatever else is learned about a map may be useless.

Experiment 3

Since the degree of integration between map elements is obviously an important factor in learning, one may look for aids which could have an effect on the ties between map schemes. One possibility is to increase the number of associations between map elements by providing an additional network of schematic organization of the map elements. For example, one can accompany learning a map with reading a story which uses the map as its background. Such a story would describe idiosyncratic relations between some cities or between a city and a nearby landmark, something that cannot be seen from the map itself.

The attempt to study one single factor of a complicated task presents a serious control problem. Reading the story and following the scenes on the map as they are described forces the subjects to observe the map closely and continuously, going back and forth from the map to the story. A control group could simply be asked to look at the map while the experimental group is still busy with the stories, but it would be impossible to know what the subjects are really doing or if they are exerting equivalent effort in processing the map, compared to the experimental group. In this experiment I required the control group to copy the map, thereby forcing them to continue to process the map visually. This solution is far from perfect, of course, since copying the map is again another level of processing. Thus, what the experiment really compares are two different means of processing, one by drawing and the other by constructing story propositions on top of the ordinary visual learning of the map.

Method

Two groups were given a map to study for about 3 minutes. In addition, one group was asked to copy the map on a blank sheet of paper and the other group was asked to read two stories which have the map as the background of the events described (see Appendix A). Time of working on the two tasks was equal for both groups (about 6 additional minutes).

Ten subjects served in the "stories" group and 9 subjects served in the "copying" group. Subjects were undergraduate students at the University of California, San Diego, whose participation in the experiment was part of the requirements of an introductory course in Psychology.

Results and Discussion

The results of this experiment show that all three of the measures which yielded significant differences favored the "stories" group (see Table 3). Reading the stories while observing the map apparently made the associations between cities and routes more powerful. It enabled this group to answer the more difficult questions (e.g., recall of the cities between two end points, and the realization of spatial representation of a list of ten cities). The overall organization of map elements by integrative processes seems to have been improved by the use of a story.

These results fit nicely the intuitive feeling we have in reading stories where a map is a necessary aid. We usually find that with the story the map is better learned and better retained. Apparently, associations between map elements are being strengthened by the propositions of the stories.

Table 3

Mean percentage of correct scores in categories of map learning for a group who learned the map while reading stories relevant to the map and for a group who learned the map by copying it. In the "stories" group N = 9 and in the "copying" group N = 10.

Categories of Map Memory and Examples	Stories	Copying	Statistics
1a. Edges of the coordinate system (i.e., What is the most northern city?)	97	92	N.S.
1b. Orientation between cities (i.e., Which city is directly south of A?)	77	70	N.S.
2a. Associations to nearby cities (i.e., Which city is between A and C?)	95	83	N.S.
2b. Associations to nearby landmark (i.e., Which city is in the mountains?)	88	89	N.S.
3a. Associations between cities and routes (i.e., Name two cities on Rt. 5)	90	67	$t = 2.77$ $p < .05$
3b. Recall of all the cities along a route (i.e., Name the cities on Rt. 7 going south)	75	79	N.S.
4a. Cities between end points (i.e., Name the cities from A to D)	87	67	$t = 2.13$ $p < .05$
4b. Recall by spatial organization (i.e., Repeat these ten names. . .)	60	22	$z = 1.69$ $p < .05$

Within the recent literature about the relationship between visual imagery and reading comprehension, some studies suggest that visual illustrations can sometimes improve the comprehension and the memory of a text (Lesgold, Levin, Shimron & Goottmann, 1975). Thus, maps and stories may mutually aid one another: Reading a story may improve the learning of a map; observing a map may improve the learning of a story.

General Summary

The purpose of this study was to detect psychological processes involved in learning maps. Map information seems to be organized by: (a) general map concepts (schemes), such as highways, rivers and mountains; (b) identifying familiar shapes and associating locations with each shape; (c) locating shapes and schemes within the coordinates of the map; (d) encoding relations hich specify how the several schematic organizations are correlated.

The results suggest that: (a) learning a map is a gradual process whereby local connections between map elements are learned first and overall integration of the map units is only later achieved; (b) learning map information is facilitated if the learner can observe how map units are simultaneously organized; (c) those who learn a map scheme-by-scheme (e.g., the highways separately from the river and the mountains) may have difficulties in relating one kind of schematic organization to another; (d) propositional information in stories helps to organize and improve retention of map information in memory.

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Appendix A: The Stories Used in Experiment 3

The Lady

Janet Smith was the wholesale lady for Tamara county. She was responsible for the sales of the latest development in girdle craftsmanship-- the Nogimmick computerized girdle. This girdle has a minicomputer built into it. When a woman puts the girdle on, it computes which areas it needs to apply its effort. The user can control exactly where and how much effort the girdle will exert. The new product enjoyed a very good market, but there was some reluctance on the part of new users to use any girdle, and some older clientele were suspicious of an electronically controlled device.

Janet Smith lived in Sunyside, the southern city in Tamara county. To see her sales route, look at the map. She sold the girdles three days a week. On Monday, Smith would follow route 5 north, going to Danville, Burkesville and Alton. This took care of the three cities on the east. On Wednesday, she would go north along Route 7, paralleling the river, going to Forsyth, Maysville and Quincy. This took care of the three central cities. On Friday, she would follow Interstate 11 north to Humbolt and Romney, and then turn west to Greenfield. This covered the last three cities.

Monday was the easiest day. The ladies in Danville, Burkesville and Alton needed many girdles. The cities were in the countryside, and evidently the ladies had little exercise. Wednesday was the hardest day, for no one seemed interested in girdles. The cities of Forsyth, Maysville

and Quincy were located near the river. The ladies in these cities were very athletic, and they swam in the river during the summer and ice skated on it during the winter. As a result, they exercised a lot and did not really need girdles. On Friday, the job was not as easy as on Monday, but not as difficult as on Wednesday. Humbolt was located by the river and few girdles were needed there. Romney was neither on the river nor too far away. Only Greenfield, to the west, was in the country. Indeed, many ladies in Greenfield used girdles.

Janet Smith could, of course, use other routes in her traveling. She could go from Forsyth, through Alton, to Quincy. (See the map.) But going this way, she would have to go through the mountains around Alton. She could also go from Maysville to Romney and Greenfield, but the bridge between Maysville and Romney was often flooded during rainy days. The bridge between Humbolt and Romney was much safer.

Smith always reserved motel rooms in the three end cities. Thus, on Monday, she reserved a room in Alton (the city in the mountains), on Wednesday, she reserved a room in Quincy (the most northern city), and on Friday she reserved a room in Greenfield (the most western city). She did this in case the weather turned out to be stormy and it would not be safe to return home in the night time.

The Sociology Project

Jacob and Sophie, seniors majoring in Sociology, were doing a project administering a questionnaire to the directors of the Unemployment offices in the cities of Tamara county. Their goal was to observe the distribution of unemployment. More specifically, they wanted to discover if there was any correlation between the kind of industry each city had and the rate of unemployment. Look at the map of Tamara county. A wide river flows from north to south in the western part of the county. This river provided a cheap means of transportation for the county and the four cities along it: Quincy, Maysville, Forsyth and Humbolt. These four cities developed a heavy industry based on coal and metals which they received by river from neighboring counties. The cities on the east side of the county--Burkesville, Danville and Sunyside--were not able to use the river, had to be satisfied with the less heavy industry such as the production of kitchen appliances, and office equipment.

Alton was the only city in the county in the mountains. Alton became a tourist center. In the winter, people came to ski. During the summer, people came to hike and picnic. Most of the people in the city were involved in the tourist industry. To the west of the river was Romney and Greenfield. Romney was a trade center. It was located on the main highway and had many wholesale distributors that served all Tamara county as well as other neighboring areas. Greenfield was a small town: its basic product was agriculture.

When Jacob and Sophie planned their project, they wondered what would be the most efficient way to cover the county. Since they came from the south, the first city they would reach was Sunyside. One proposal was to deal first with the eastern cities--Sunyside, Danville, Burkesville and Alton--on their first day, to visit the river cities--Quincy, Maysville, Forsyth and Humbolt--on their second day, and to conclude with Romney and Greenfield on their third day.

Their second proposal was to visit the southern cities--Sunyside Danville, Burkesville and Forsyth--on their first day, to visit the northern part of the county--Alton, Quincy and Maysville--on their second day, and to conclude with the cities along Interstate 11--Romney, Greenfield and Humbolt--on the last day.

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